CHALMERS

Chalmers Publication Library

Over-the-air performance testing of wireless terminals by data throughput measurements in reverberation chamber

(article starts on next page)

Over-the-Air Performance Testing of Wireless Terminals by Data Throughput Measurements in Reverberation Chamber

Anton Skårbratt, John Åsberg, Charlie Orlenius

Bluetest AB

Götaverksgatan 1, SE-41755 Gothenburg, SWEDEN

{anton.skarbratt, john.asberg, charlie.orlenius}@bluetest.se

***Abstract*— This paper discusses the possibilities of using the reverberation chamber as a multipath emulator for testing of wireless terminals, especially those with multi-antenna solutions implemented. The tests are consisting of measurements of data bit throughput, in order to relate the performance of the terminal to an end-user experience. The experimental part includes HSDPA measurements with focus on overall system performance in different channel models, and LTE measurements of individual antenna parameters.**

Keywords – HSDPA; LTE; MIMO; reverberation chamber; throughput;

I. INTRODUCTION

This paper elaborates on the recent trend in wireless device testing, where performance measurements are constructed to reflect end-user experience. This is in contrast to traditional antenna characterization, where direct measurements of antenna parameters have dominated. End-user experience in a wireless system is in the modern context often expressed as data bit throughput, i.e. the amount of bits delivered over the wireless data interface to the user. Throughput will not explicitly tell the performance of an antenna since it is an overall system performance parameter and depends on several components of the system, such as antennas, receivers, and software. However, modern communication systems with built-in multi-antenna technologies like diversity and MIMO, are complex in itself which makes it difficult to set up specific tests for each of the many components in the system. This is especially true since many of the system components interact and rely on each other. Therefore, overall system tests are an alternative to traditional single component measurements.

By using overall system tests like data bit throughput measurements, single component characteristics can still be analyzed by setting up well-defined scenarios where only the component of interest is varied.

The recent and rapid growth for units with multi-antenna configuration within the wireless industry has called for completely new ways of characterizing these devices. Traditionally, antenna characterization has been performed in anechoic environments in order to determine the performance of the specific antenna in a point-to-point sense. This is no longer enough, since multi-antenna terminals are used in a multipath scattering environment, and also requires this type of signal environment to reach the intended performance enhancement. In order to test a multi-antenna terminal for such a system, the straight-forward approach is to emulate a multipath scattering environment in which the performance of the device is measured. There are some different approaches to do this, and this paper will focus on the possibilities of doing this in a reverberation chamber (RC).

The reverberation chamber is a well-used measurement range for performance characterization of wireless devices and small antennas. It can be used for measurements of antenna parameters such as radiation efficiency, impedance mismatch, diversity gain, MIMO antenna capacity, as well as active device parameters such as total radiated power (TRP) and total isotropic sensitivity (TIS). Descriptions of these measurement setups are readily found in previous publications [1-5].

II. CHANNEL EMULATION

For emulation of the signal properties of a multipath scattering environment, one has to take into account both the spatial, frequency, and temporal domains. The spatial domain characteristics produced by a reverberation chamber are isotropic [6], i.e. signals are statistically distributed in such a way that any angle of arrival is equally probable.

Main characteristics of time and frequency domains are the power-delay-profile (PDP) and Doppler spectrum [7]-[8]. These can to some extent be varied by loading the reverberation chamber and varying the speed of the mode-stirrers, but more advanced channel models can also be produced by adding a channel emulator instrument to the setup.

The article will describe the different possibilities of channel emulation with the proposed setup, together with a discussion of feasibility and whether there is a need for different channel models when characterizing wireless terminals.

III. MEASUREMENT SETUP

All measurements in this article were performed in a Bluetest reverberation chamber, which utilizes a combination of three mode stirring techniques; mechanical, polarization and platform stirring. The inner cavity size of the chamber is 1.75 x 1.8 x 1.2 m and it has a frequency range of 650-6000 MHz. Two measurement setups was used, one for HSDPA and one for LTE.

A. HSDPA SIMO Measurements

Figure 1 shows the principle of the basic measurement setup, with the device under test (DUT) placed in the reverberation chamber, and the base station simulator connected to the fixed measurement antennas of the chamber. The reverberation chamber itself will produce a uniform channel model with an exponential decaying PDP. The RMS delay spread of this PDP can be varied by loading the chamber with absorbing material, and typical values that can be realized range between 30-200ns. For the HSDPA measurements the chamber was tuned in to an RMS delay spread of 90ns. This corresponds to the NIST Indoor-Urban channel model, which is based on real outdoor-to-indoor channel measurements [9].

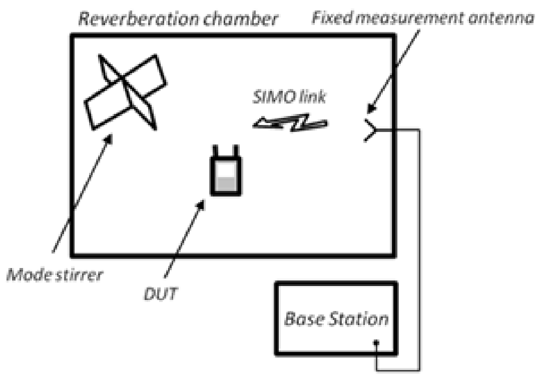

Fig. 1 Setup with reverberation chamber for active data throughput measurements in HSDPA mode.

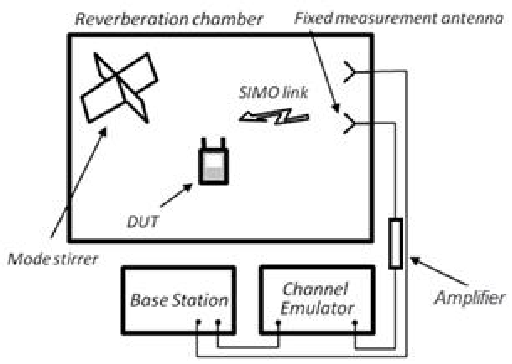

Fig. 2 Reverberation chamber together with channel emulator to produce more advanced channel models for HSDPA throughput measurements. Note that the uplink and downlink are separated.

It is also of interest to measure throughput in more advanced channel models and compare results with the uniform model. These more advanced channel models were created by connecting an Azimuth ACE-MX channel emulator between the RC and base station simulator, as illustrated in Fig. 2. More specifically, it was used to create two spatial-channel-model-extended (SCME) models; the urban micro cell and the urban macro cell. These models have been developed to resemble dense urban settings from the real world and are described in for instance [10].

The aim of the HSDPA measurements was to investigate the overall system performance for different DUTs in the channel models described above. In particular, it was important to be able to differentiate between good and bad devices. The method should also be repeatable and reflect end-user performance in real environments.

Unless it is explicitly stated in the figure text, all HSDPA measurements were performed with an Agilent 8960 on UMTS band 1, downlink channel 10562 (2112.4 MHz).

B. LTE MIMO Measurements

While the HSDPA measurement setup aimed primarily to investigate overall system performance of different DUTs, the LTE measurements focused on changing parts of the system for the same DUT. The two most interesting variable parameters were correlation and gain imbalance of the DUT's MIMO-antennas. These two parameters were varied by connecting external antennas to an LTE enabled USB modem (Huawei E398). The USB modem had to be placed in a separate shielded box since several LTE networks were already deployed near the lab, and to ensure that the modem's built-in antenna did not contribute to the received signal.

The measurement setup is illustrated in Fig. 3. The RMS delay spread of the reverberation chamber was tuned in to 90 ns. An R&S CMW500 was used as base station simulator and measurements were performed on LTE band 7, channel 2850 (2630 MHz).

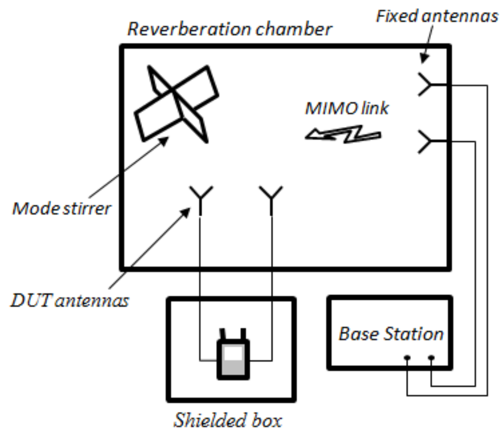

Fig. 3 Using the reverberation chamber for LTE throughput measurement with external antennas connected to the DUT. Note that the DUT is placed in a separate shielded box.

IV. Results and Discussion

Fig. 4 shows results from measurements in the uniform channel model, where the average throughput as a function of average available power is presented for three different DUT's. Measurements were performed in HSDPA mode, and each device was tested several times at different occasions to verify the repeatability of the measurement setup. The results clearly show that it is possible to differentiate between good and bad DUTs. DUT A was a laptop with a built-in modem and with the antennas implemented in the display. DUT B and C were two external USB modems of the same model hosted on two different laptops. The fact that the external modems showed different results between two different laptops indicates that laptop noise most likely affect throughput performance. The performance variations could also be explained by device differences within the same model, or by differences in the ground planes of the host laptops.

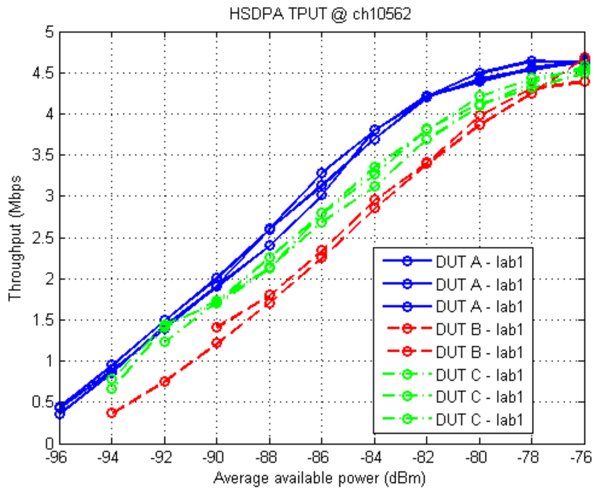

Fig. 4 Average throughput for three HSDPA devices measured in reverberation chamber. Each device has been tested two or three times at different occasions.

DUT A and B were also tested with lower maximum throughput settings (H-Set 3) in two different labs to show the inter-chamber repeatability. Results are presented in Fig. 5 and note that the maximum throughput was reached at approximately the same average available power as before. The DUT ranking is still the same, with DUT A performing several dB better than DUT B.

Fig. 6 shows results from the SCME urban models created with the channel emulator. The maximum throughput is no longer reached, regardless of power level, and the DUT ranking has changed. This kind of change in performance is not related to the antennas, but to the receiver. When choosing channel model/models for OTA testing it is therefore important to understand what the measurement aim to test. A standalone reverberation chamber can effectively test and differentiate between good and bad DUTs in a repeatable and real world resembling environment. To predict how the receiver will perform in different complex radio channels, a channel emulator is needed. For this purpose the channel emulator can be used alone with conductive testing of the device, or in combination with a reverberation chamber to test the over-the-air (OTA) performance.

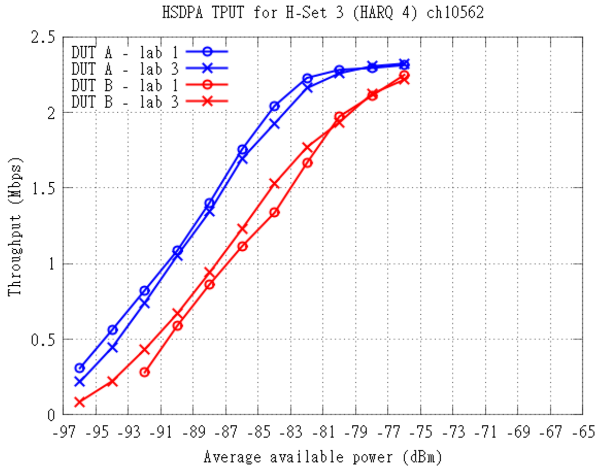

Fig. 5 Average throughput for three HSDPA devices measured in reverberation chamber. The DUTs are measured in two different labs to show the inter-lab repeatability. Lab 1 employed an Agilent 8960 as communication tester while lab 3 used an Anritsu MT8815B.

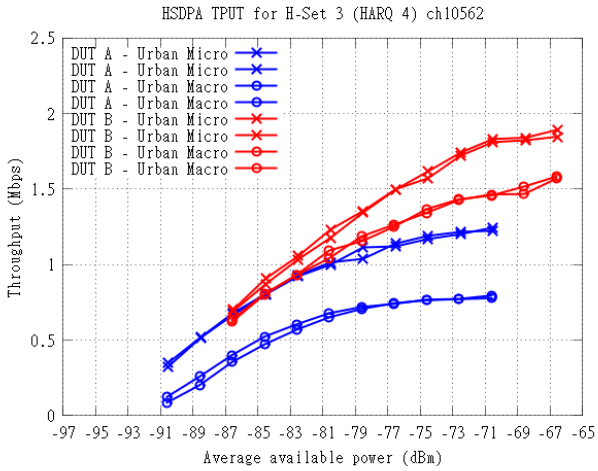

Fig. 6 Average throughput for three HSDPA devices measured in reverberation chamber together with a channel emulator to produce the SCME urban models. Each device has been tested two times to show the repeatability.

For the LTE MIMO measurements, two different MIMO antennas were used to investigate how correlation affects the MAC layer throughput. Both antennas have been developed by Sony Ericsson for this purpose and were implemented on mobile phone sized PCBs. The low correlation device consisted of two miniature ceramic WLAN/BT antennas placed on each of the two long-sides of the PCB. This device is denoted antenna D and had a power correlation of 0.2. Since its normal operating frequency was 2.45 GHz, the branch efficiencies were relatively low at the measured channel with values of -4.9 dB and -5.7dB. The high correlation device, denoted antenna E, had a power correlation of 0.6. It consisted of a dual feed PIFA near one of the short sides of the other PCB and was intentionally designed to produce a worse performance than antenna D. The branch efficiencies were -3.2 dB and -4.6 dB. By connecting these two MIMO-antennas to the same LTE modem in the way described in Fig. 3, it was possible to observe correlation effects on throughput without changes in other parameters.

Remembering that the joint contribution of correlation and efficiency decide the overall performance of the MIMO-antenna, it could still be interesting to see the pure effect of correlation in some cases. Therefore, the efficiency difference between the two MIMO-antennas was accounted for and the new results plotted in a separate figure.

Fig. 7 presents throughput results for the different MIMO-antennas with two measurements on each device. The repeatability is very good and it is easy to distinguish between a good and a bad MIMO-antenna. The results actually indicate that it would be possible to detect small changes in correlation (0.05-0.1) just by looking at the throughput.

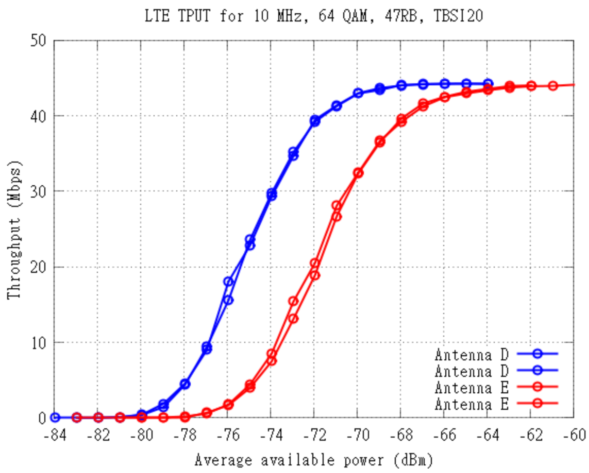

Fig. 7 Average throughput for two different types of antennas measured in reverberation chamber. Antenna D (power correlation 0.2) is much better than antenna E (power correlation 0.6) in an end-user sense.

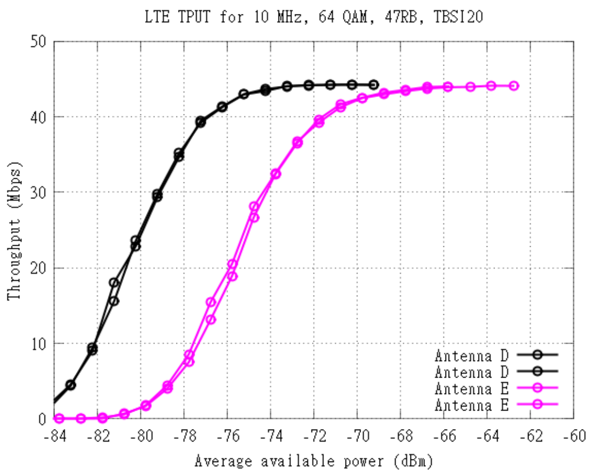

Fig. 8 Average throughput for two different types of antennas measured in reverberation chamber. The total radiation efficiencies have been subtracted from both antennas to illustrate the throughput difference due to correlation only.

The efficiency corrected throughput in Fig. 8 show a larger difference between the two MIMO-antennas. Even though the gain imbalances were not corrected for here, this result highlights the importance of optimizing both efficiency and correlation when designing small multi-antenna solutions.

The other part of the communication system that was tested was the gain imbalance between the two antenna branches. This test was created by adding attenuators to one of the antenna signal paths, between antenna D and the LTE modem. As can be seen in Fig. 9, measurements were performed twice to ensure that possible differences were not caused by measurement uncertainty. It is clear from the figure that all tested values of gain imbalance are possible to detect by the means of throughput measurements.

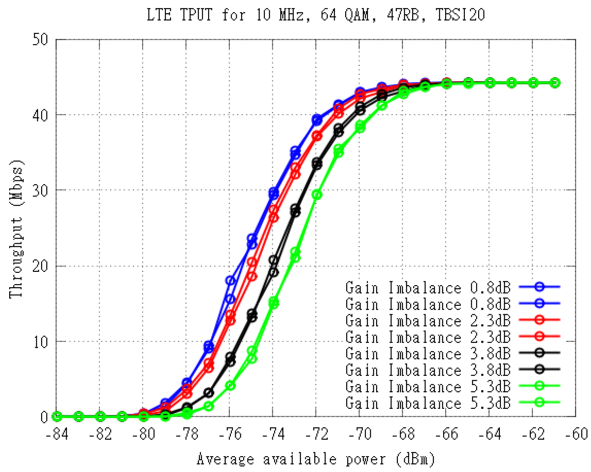

Fig. 9 Average throughput for different cases of gain imbalance, starting on 0.8 dB and then increasing with 1.5 dB steps.

V. Conclusions

A procedure for testing wireless devices based on throughput measurements has been suggested for the reverberation chamber alone, as well as in combination with a channel emulator. Results show that it is possible to distinguish between a good and bad device in a repeatable way in both measurement setups. The ranking between devices can however vary between channel models, mainly since the receivers handle signal delays differently. It was also shown that individual system parameters, such as correlation and gain imbalance, can easily be analyzed with throughput measurements by setting up well-defined scenarios where only the component of interest is varied.

Acknowledgment

This work has been carried out in the Chase VINN Excellence Center at Chalmers University of Technology, Gothenburg, Sweden.

References

[1] M. Andersson, A. Wolfgang, C. Orlenius, J. Carlsson, "Measuring Performance of 3GPP LTE Terminals and Small Base Stations in Reverberation Chambers", Chapter 12 of "Long Term Evolution: 3GPP LTE Radio and Cellular Technology", CRC Press, 2009.

[2] P-S Kildal, ”Overview of 6 Years R&D on Characterizing Wireless Devices in Rayleigh Fading Using Reverberation Chambers”, International Workshop on Antenna Technology (iWAT07), Cambridge, UK, pp. 162-165, (2007)

[3] K. Rosengren and P.-S. Kildal, “Radiation efficiency, correlation, diversity gain, and capacity of a six monopole antenna array for a MIMO system: Theory, simulation and measurement in reverberation chamber”, Proceedings IEE, Microwave Antennas Propagation, vol. 152, no. 1, pp.7-16, February 2005. See also Erratum published in August 2006.

[4] N. Olano, C. Orlenius, K. Ishimiya, Z. Ying, “WLAN MIMO throughput test in reverberation chamber”, IEEE International Symposium on Antennas and Propagation (IEEE AP-S), San Diego, CA, July (2008).

[5] C. Orlenius and M. Andersson, “Repeatable performance measurements of MIMO systems in connected reverberation chambers with controlled keyhole effect”, Radioengineering, Vol. 18, No. 4, Dec. 2009.

[6] K. Rosengren and P.-S. Kildal, ”Study of distributions of modes and plane waves in reverberation chambers for characterization of antennas in multipath environment”, Microwave and Optical Technology Letters 30 (20), pp. 386–391, 2001.

[7] X. Chen, P.-S. Kildal, C. Orlenius, J. Carlsson, “Channel sounding of loaded reverberation chamber for Over-the-Air testing of wireless devices - coherence bandwidth versus average mode bandwidth and delay spread”, IEEE Antennas and Wireless Propagation Letters, vol. 8, pp. 678-681, 2009.

[8] K. Karlsson, X. Chen, P.-S. Kildal, J. Carlsson, "Doppler spread in reverberation chamber predicted from measurements during stationary step-wise stirring", Antennas and Wireless Propagation Letters, Vol. 9, pp. 497 - 500, 2010.

[9] D. W. Matolak, K. A. Remley, C. L. Holloway, “Outdoor-to-Indoor Channel Measurements & Models”, 14 Sep. 2009. [Online]. Available: http://www.nist.gov/

[10] Tdoc R4-100864, “Test Plan for MIMO OTA Methodology Comparison”, Nokia et al, 3GPP RAN4 #54, San Francisco, CA, USA, 22-26 February 2010.